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Research article

Environmental sustainability and prevention of heavy metal pollution of some geo-materials within a city in southwestern Nigeria

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ABSTRACT

Increased anthropogenic activities may cause the release of potentially hazardous metals into the environment. This is a major public health concern. The study was aimed at accessing ways by which pollution can be prevented with enhanced environmental sustainability in Ibadan, Southwestern, Nigeria. Geo-materials (groundwater, soil and stream sediment) were collected, analyzed for heavy metals using inductively coupled plasma-mass spectrometry. Results of acidity (pH), electrical conductivity (EC), total dissolved solid (TDS) and heavy metals (Zn, As, and Cd) obtained in water were compared with WHO permissible limits. All parameters were found within WHO permissible limits except TDS (624.35 mg/L). Risk index showed dangerous to extremely dangerous. High TDS can be attributed to weathering while high Cd, Zn and Pb in stream sediment and soil are due to anthropogenic effect. Provision of adequate disposal facilities should be created by private and government agencies and the use of it must be enforced.

1. Introduction

Increase in human activities with lack of adherence to environmental protection laws has led to indiscriminate discharge of unwanted substances into the environment. The effect of this discharge results in different forms of pollution in most developing countries such as Nigeria. Pollution is defined as a release of harmful unwanted materials that comes through excessive discharge of harmful gases (CO, SO_2, NO_2) and all forms of wastes. These unwanted materials eventually bring out potentially hazardous element known as "heavy metal" (major and trace) such as arsenic, lead, copper, cadmium. These metals when released in concentration above the acceptable value become toxic in the air, waters (ground and surface), stream sediment, soil and it invariable gets into man through the food-chain (GWRTAC, 1997; Singh, 1997). Therefore, ways on how to reduce the emission of these metals (in: industries, hospitals, houses, pharmaceutical and production companies), that may become toxic with constant emission into the environment must be harnessed to conserve the environment from pollution (Hawken, 2007). Environmental sustainability is the act of having responsible interaction with the environment to prevent degradation of natural resources. Environmental sustainability allows for a long-term environmental quality that is not only on the environment (Kates et al., 2005; Thiel et al., 2015), but also interfaces with the public health. The act of environmental sustainability meets the present societal needs without affecting the rights of future generations. It also ensures checking of future impact of the human activities and how it can be sustained (Elleuch et al., 2018; Sherman et al., 2016; World Commission on Environment and Development, 1987).

Soil, stream sediments, waters (surface and ground) and air are crucial component of the environment that becomes altered due to uncontrolled release of potentially hazardous elements (Chibuike and Obiora, 2014; Xie et al., 2016). These metals find their ways into the soil and gets contained without being exposed or washed off (because soil has the ability to contain metals) (Khan et al., 2008; Zhang et al., 2010), from the soil, this contained metals then moves into the groundwater through leaching (Adriano, 2003; Kirpichtchikova et al., 2006). Vegetables cultivated on such soils bio-accumulate the metals easily; thus becoming a major environmental menace through the food chain posing risk and hazard to public health (Ji et al., 2018, Ling et al., 2007; Maslin and Maier, 2000; McLaughlin et al., 2000a, 2000b).

These chemical elements when found in their right proportion and combination in the water, soil and stream sediments becomes useful for the growth and development of man and the ecosystem (Maslin and Maier, 2000; McLaughlin et al., 2000a, 2000b). High concentration of these metals exceeding the permissible limits that comes from both

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natural and human activity makes the metals injurious to the health of human, aquatic wildlife and the environment (Brkovic – Popovic and Popoola, 1977; Godbold and Huttermann, 1985; Powlesland and George, 1986; Wicklif and Evans, 1980). Examples of severe issues linked to prolonged susceptivity to these metals include mental lapse through Pb poisoning, divers incurable diseases from Cd or As poisoning, and many others.

Increase in creation of various industries, artisanal mining, water run-offs from industries, hospitals, homes, markets could infiltrate the environment with toxic metals. Work done by several researchers revealed that altering the earth's surface chemistry and subsurface water/soil may give more severe consequences. Altering the earth surface may occur during mining (especially: artisanal); all forms of industrial and domestic activities, that release wastes indiscriminately thereby resulting in deterioration of geo-materials (Howard and Beck, 1998; Elueze et al., 2003; Fakayode and Olu-Owolabi, 2003; Odewande and Abimbola, 2008; Tijani et al., 2004). The research becomes imperative because alteration in permissible limit of water and soil enhances poisoning and danger to the environment (Sandroni and Smith, 2002). Therefore, evaluation of the magnitude of heavy metal poisoning of soil, stream sediment and groundwater found in the study area was done and the most appropriate way to sustain the environment provided.

1.1. Study location

Northing and easting of the area are $7^0 20^1$–$7^0 23^1$ N and $3^0 53^1$ to $3^0 56^1$ E respectively (Figure 1). The study was conducted in Ibadan. Ibadan is the largest indigenous city in sub-Sahara with an estimated population of 2, 554,593 (NPC, 2006). The growth of the city has nothing to do with industrialization (with only few industries) but associated to age long role of the city as regional administrative capital since the colonial era. Ibadan is characterised with improper discarding of waste (solid and liquid). This implies that many households within the congested central part of the city lack toilet and waste disposal facilities (Tijani and Ayodeji, 2002; Tijani et al, 2004, 2007; Tijani and Agakwu, 2007). The household therefore, defecate and discharge their waste straight into water bodies thereby reducing the quality of water found in the area.

2. Materials and method

The method used to collect samples was random sampling. Twelve (12) hand-dug well samples were collected into a 10 ml plastic bottle. Before collection into the plastic bottles; the bottles were washed thoroughly with the water to be collected. This is to avoid/reduce contamination, that may occur through direct use of the plastic bottle. Two drops of concentrated hydrochloric acid pippeted in a syringe were then injected into the water samples collected. This helps metals to maintain their normal state prior to laboratory analysis. A rubber bucket expected to introduce least contamination was used to draw water from the hand-dug well, because the sampled water is at a considerable depth below the ground surface. The rate of acidity was measured with pH meter while electrical conductivity (EC), total dissolved solid (TDS) were measured with conductivity meter. Nine soil samples and four stream sediment were collected irregularly at depths not exceedingly 5cm in the various locations (Figure 1). In the stream sediment sampling, to avoid contamination bank of the stream was not sampled. Portions of soil and stream sediments were decanted and placed into polythene bags using non-metallic plastic shovel. The samples were appropriately labelled on the spot to avoid mix-up. Trowel was rinsed immediately after each collection to avoid contamination of the samples. Assay of the portions were done using inductively coupled plasma – mass spectrometer at the Acme Analytical Laboratories, Canada. Results from the analysis were interpreted using different statistical evaluations such as anthropogenic factor, contamination factor, risk and geo-accumulation index. The indices were expressed as follows and their classification schemes shown in (Table 1).

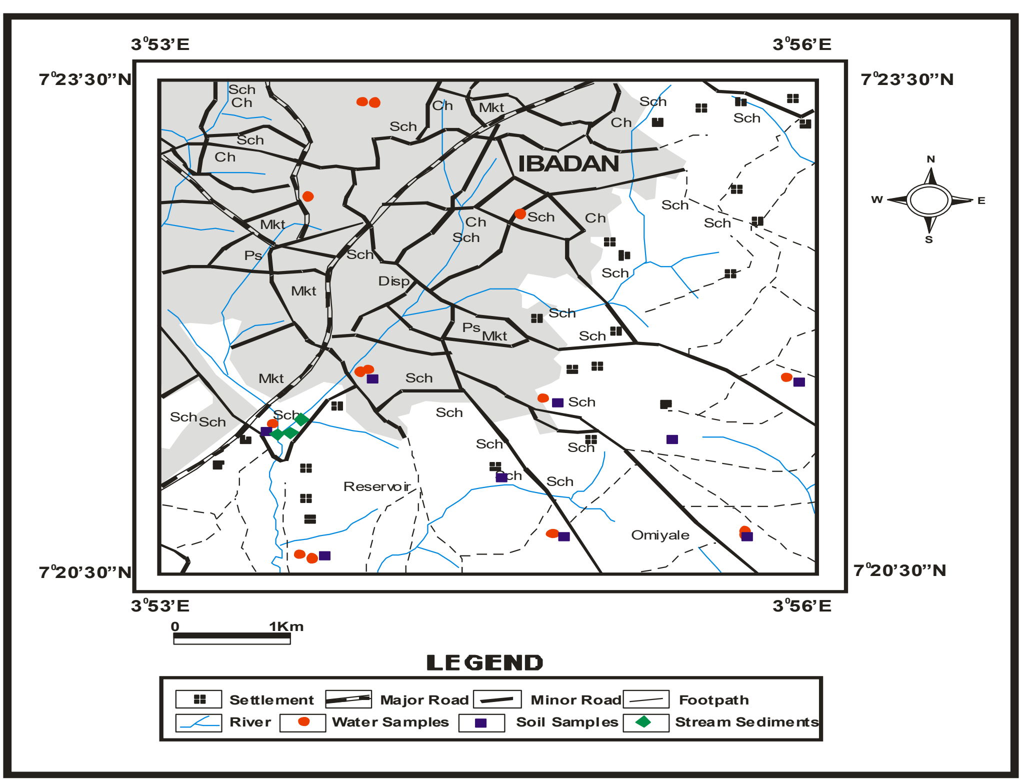

Figure 1. The sample location points.

Table 1. Descriptive classes of Geo-accumulation index contamination factor risk factor.

CLASSES	RANGES	INDICATION/WATER QUALITY
Geo-accumulation index classes (Muller, 1969)		
0	$I_{geo}<0$	Practically uncontaminated
1	$0 < I_{geo}<1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo}<2$	Moderately contaminated
3	$2 < I_{geo}<3$	Moderately to heavily contaminated
4	$3 < I_{geo}<4$	Heavily contaminated
5	$4 < I_{geo}<5$	Heavily to extremely contaminated
6	$5 < I_{geo}<$	Extremely
Risk index (Ko)		
Contamination Level	Ko Value	Required Actions
Permissible	Ko_<1	Detailed soil investigation and monitoring is recommended
Medium dangerous	1 < Ko_<3	Reducing of impact from pollution sources. Quality control of surface and ground water
Dangerous	3 < Ko <_10	Obligatory is soil remediation (liming, adding with clean soil) up to permissible level in residential and recreation areas. agriculture areas must be used for technical crops or afforestation
Extremely dangerous	Ko > 10	Polluted soil layer must be removed to landfill of hazardous substances or remediated insitu up to superior level of contamination.

2.1. Data evaluation for soil and stream sediment

To assess the impact of contamination on the geologic media certain indicators was used. Indicators used are (Table 1); Anthropogenic Factor (A.F), Index of geoaccumulation (I_{geo}) and Risk index (K_o).

*Index of Geoaccumulation (I_{geo}) – helps in measuring the extent of metal contaminated in the biome is expressed:

$$I_{geo} = \log_2 \quad Cn / 1.5 \times Bn$$

Cn - concentration of element in the sample, Bn - geochemical background value (i.e. average crustal abundance of the area study) of the element and 1.5 - matrix factor for possible variation in the background concentration due to lithologic differences. Geochemical index proposed by Muller (1969) is shown in Table 1.

* Risk index. (K_o) Risk index K_o, calculated by: $K_o = C/MPL$

C - Content of particular element in the soil (mg/kg)

MPC- maximum permissible concentration of the same element (mg/kg)

Major oxides were also evaluated for some metals in the soil and stream sediment to ascertain the effect of organic matter on the environment. Correlation and factor analysis were evaluated for water, soil and stream sediment, this assessment helps to describe the main source of these metals. The analysis helps to describe if the metals are from the same environment or they are not from the same environment. Piezometric map was drawn to describe the flow direction of the water. The flow direction helps to describe the rate of flow of contaminants into the environment.

Statistical analytical method used was done by MS-Excel and the software used for correlation, factor analysis, peizometric map were SPSS.

3. Results

3.1. Water samples

Physico-chemical parameters collected (TDS, EC, pH) were compared with WHO (2013), the results was also compared with the work of Islam et al. (2016) since similar research work was done by the author.

3.2. Geochemical evaluation of the metals

Heavy metal concentration of the water samples were analyzed and also compared with WHO (2013) permissible limit, results acquired helped to evaluate the impact of metal emission especially through anthropogenic means into the environment.

Results of statistical evaluation of water, soil and stream sediment.

Table 2. Physico-chemical parameters of water samples.

Location	pH	Conductivity	TDS	Remark (Islam et al., 2016)
Molete	7.73	576	205.9	Excellent
Eyin Grammar	7.23	183	119	Excellent
Kudeti	7.58	423	275	Excellent
Oke Aremu	6.81	158	103	Excellent
Owode	7.36	109	71	Poor
Muslim	6.33	132	86	Poor
Odinjo	7.83	956	**624.35**	Fair
Olorunsogo	6.72	205	133.3	Excellent
Oja Oba	8.05	523	340	Excellent
Ayeye	7.54	538	350	Excellent
WHO (2013)	**6.5–9.2**	**1400**	**500**	Excellent

Notes: Bold indicates TDS value above the permissible limit.

Table 3. Descriptive Statistics of the Heavy Metals in water, soil (s) and stream sediment (ss).

Water

Location	As (mg/l)	Cd (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	K (mg/l)	Mg (mg/l)	Ca (mg/l)	Fe (mg/l)
Molete	0.00165	0.000105	0.0065	0.00045	0.62125	**63.36**	24.525	136.9	0.01
Eyin Grammar	0.00055	0.00005	0.00335	0.00125	0.0618	**14.77**	13.925	27.5	0.0555
Kudeti	0.0009	0.00005	0.00645	0.00135	0.0209	**57.935**	10.88	62.945	0.0395
Oke Aremu	0.0005	0.00005	0.00205	0.00195	0.0467	**26.945**	6.06	24.3	0.0245
Owode	0.0005	0.00005	0.0217	0.0275	0.06575	**22.255**	5.41	11.88	0.285
Muslim	0.00125	0.00005	0.0069	0.0048	0.0981	**76.005**	15.19	56.55	0.038
Odingo	0.00175	0.00005	0.00295	0.00055	0.01505	**91.15**	33.44	51.46	0.127
Olorunsogo	0.0005	0.00005	0.0023	0.0001	0.032	7.43	18.58	16.98	0.01
Oja Oba	0.0011	0.00005	0.0061	0.0001	0.0042	**102.7**	12.58	42.61	0.01
Ayeye	0.0012	0.00005	0.0031	0.0007	0.0271	**97.68**	38.89	77.03	0.01
WHO (2013)	**0.01**	**0.003**	**2**	**0.01**	**3**	**N/A**	**100**	**200**	**0.5**

Major oxides for the soil (s) and stream sediment (ss)

ELEMENT	N	range%	minimum	maximum	mean
Fe_2O_3	s	2.17–6.06	2.17	6.06	4.04
	ss	3.30–7.15	3.3	7.15	5.23
CaO	s	0.31–2.97	0.31	2.97	1.48
	ss	0.74–0.99	0.74	0.99	0.84
MgO	s	0.08–0.48	0.08	0.48	0.27
	ss	0.22–0.98	0.22	0.98	0.41
Na_2O	s	0.01–0.07	0.01	0.07	0.03
	ss	0.01–0.03	0.01	0.03	0.02
K_2O	s	0.10–0.41	0.1	0.41	0.22
	ss	0.17–0.36	0.17	0.36	0.22

Trace elements of soils (s)and sediments (ss)of the study area

N/S	Description	Cu mg/l	Pb mg/l	Zn mg/l	As mg/l	Cd mg/l	Ba mg/l
S1	Eyin Grammar	137	2333	992	3	2.6	240
S2	Eyin Grammar	34.5	79	211	2	0.5	102
S3	Owode Academy	16	36	198	2.5	0.5	70
S4	Owode	21.5	41.5	197	2	0.5	67
S5	Surulere	57	170.5	906	2.5	0.8	101
S6	Laoye Muslim	45.5	74.5	912	2	2.1	107
S7	Kudeti	37	90.5	312	3	0.7	147
S8	Odinjo	83.5	127	2716	3.5	2.2	145
S9	Olorunsogo	20.5	53	493	2	0.5	72
	mean	**50.28**	**333.89**	**770.78**	**2.50**	**1.16**	**116.78**
	Stan dev	38.74	750.88	800.73	0.56	0.87	54.92
	Range	16–137	36–2333	197–2716	2–3.5	0.5–2.6	67–240
SS10	Ogunpa River	46	78	267	2	0.5	77
SS11	Ogunpa River	75	82	657	2	0.5	217
SS12	Elere River	77	99	285	2	0.5	81
SS13	Elere River	121	114	307	2	0.5	88
	mean	**79.75**	**93.25**	**379.00**	**2.00**	**0.50**	**115.75**
	standard	30.93	16.56	186.05	0.00	0.00	67.65
	Range	46–121	78–114	267–657	02-Feb	0.5–0.5	77–217
	Crustal Average	50	12.5	97.9	1.8	0.2	500

Notes: N/A means not available.
Notes: Bold indicates TDS value above the permissible limit.

3.2.1. Correlation analysis

Results of metals were correlated to assess their geochemical source. The geochemical source could either be anthropogenic (human activity) or geogenic (natural activity).

3.2.2. Geo-accumulation index

This helps in assessing the impact of metal contamination in the environment and how hazardous it could become when left unattended too. Geochemical background value of the region was used in calculating the result. The result calculated for was then compared with Muller (1969).

3.2.3. Factor analysis

Results of metals were placed into different factors to access their geochemical source. Factor analysis always helps in confirming the result of correlation analysis.

3.2.4. Risk index

Result of risk index provided the impact of the metal on public health especially when plants are cultivated and waters are taken without treatment.

Table 4. Correlation coefficient of heavy metals in water, soil and stream sediment of the study area.

Water

	As	Ca	Cd	Cu	Fe	K	Mg	Pb	Zn
As	1								
Ca	**0.797**	1							
Cd	0.440	**0.747**	1						
Cu	-0.219	-0.180	0.004	1					
Fe	-0.040	-0.148	-0.161	0 .050	1				
K	**0.683**	0.407	0.081	-0.117	-0.267	1			
Mg	**0.761**	**0.607**	0.239	-0.387	0.044	0.343	1		
Pb	-0.263	-0.281	-0.115	0.134	**0.900**	-0.276	-0.238	1	
Zn	0.396	0.723	**0.983**	0.000	-0.071	0.021	0.200	-0.011	1

Major oxides for the soil and stream sediment

	Na_2O	K_2O	Fe_2O_3	CaO	MgO
Na_2O	1				
K_2O	**0.623***	1			
Fe_2O_3	0.453	0.454	1		
CaO	**0.521**	0.221	0.159	1	
MgO	0.479	**0.786****	**0.628***	0.165	1

Trace elements for the soil and stream sediment

	Cu	Pb	Zn	As	Cd	Ba
Cu	1					
Pb	**0.643(*)**	1				
Zn	0.355	0.177	1			
As	0.292	0.401	**0.707(**)**	1		
Cd	0.497	**0.645(*)**	**0.724(**)**	**0.612(*)**	1	
Ba	**0.604(*)**	**0.672(*)**	0.388	0.477	**0.559(*)**	1

Notes: Bold indicates TDS value above the permissible limit.
[*] Correlation is significant at the 0.05 level (2-tailed).
[**] Correlation is significant at the 0.01 level (2-tailed).

3.2.5. Hydro-geologic interpretation

This provides information on the flow direction of the groundwater and how easily it can be polluted by organic matter.

3.3. Soil and stream sediments

In soil and sediments analysis, results of major metals were converted to their percentages for them to get into their oxide form and their respective mean was evaluated. Trace metals in soil and sediments were compared with the mean crustal average for soil and stream sediment.

4. Discussion

4.1. Water samples

4.1.1. Physico-chemical analysis

Physico-chemical parameters (pH, EC, TDS) were compared with WHO, (2013) permissible limits. Outcomes were observed to be within the permissible limits. TDS was however found to be from poor (<100.00 mg/L) to excellent (100.00–600.00 mg/L) to fair (600.00–900.00 mg/L). Total dissolved solids (TDS), a measurement of the amount of dissolved ions in water, comprised mainly of inorganic salts such as calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates. These salts gets polluted when high organic salts from various water run-offs (industrial, sewage, agricultural), divers chemicals from human activities gets into the water source.

High TDS, in accordance to WHO in the study was owed to elevated level of organic matter and indiscriminate disposal of dumps (Table 2).

This is however, similar to the work done by Islam et al. (2016) study, and it revealed the high impact of organic matter in the area of study.

4.2. Geochemical evaluation of the metals

Statistical analysis of the major elements indicates decreasing order from K (7.43–148.70), Ca (8.8–139.9), Mg (2.95–46.29) to Fe (0.01–0.56) (K > Ca > Mg > Fe) and mean of 53.69, 51.79, 16.99 and 0.07 respectively. While the range for trace elements revealed a decrease order from Zn (0.00–0.64), Pb (0.00–0.05), Cu (0.00–0.03), As (0.00–0.00) to Cd (0.00–0.00), (Zn > Cu > Pb > As > Cd) with mean 0.1131, 0.0065, 0.0045, 0.0010 and 0.00002 respectively. The metals were compared with (WHO 2013) permissible standard (Table 3) and was observed to be within the permissible limit, even though K was found to be high in the area it does not have a specific concentration in WHO standard because K occurs in drinking-water at concentrations well below those of health concern. Inter-elemental analysis of K revealed a positive but weak correlation in the groundwater while a negative correlation was also observed, all of which is pointing to the fact that K comes more from geogenic source and decayed plants than from anthropogenic source. Potassium may cause health issues in people with high risk these are those with kidney dysfunction or other diseases, such as heart disease, coronary artery disease, hypertension, diabetes, adrenal insufficiency, pre-existing hyperkalaemia; people taking medications that interfere with normal potassium-dependent functions in the body; and older individuals or infants (WHO 2020). High K was due to dissolution of minerals such as feldspar and mica through weathering processes, and also from unclear decayed plant material found in the study area. High rate of Potassium could be associated to the weathering of bedrock, which gets into the groundwater through leaching. Excessive influx of K into the environment causes a major disease known as hyperkalemia (Wright 2017) with mark of malfunctioning of the kidney, which could lead to disturbing heartbeats, and other severe diseases (Tables 3 and 4).

Table 5. Geo-accumulation Index for water, soil and stream sediment samples.

Water samples

	Locations	As	Cd	Cu	Pb	Zn
W1	Molete	0.047	0.037	-0.081	-0.534	0.256
W2	Eyin Grammar	-0.073	-0.053	-0.162	-0.534	-0.1120
W3	Kudeti	-0.020	-0.053	-0.112	-0.534	-0.317
W4	Oke-Aremo	-0.097	-0.053	-0.262	-0.534	-0.110
W5	Owode	-0.097	-0.053	0.160	-0.534	-0.182
W6	Muslim	-0.097	-0.053	-0.012	0.036	0.029
W7	Odingo	0.047	-0.053	-0.129	-0.534	-0.536
W8	Olorunsogo	-0.097	-0.053	-0.187	-0.534	-0.127
W9	Oja Oba	0.006	-0.053	-0.060	-0.534	-0.392
W10	Molete	0.070	0.050	-0.028	-0.262	0.265
W11	Eyin Grammar	-0.097	-0.053	-0.118	-0.118	0.008
W12	Kudeti	-0.020	-0.053	-0.012	-0.108	-0.118
W13	Oke Aremo	-0.097	-0.053	-0.162	-0.058	-0.052
W14	Owode	-0.097	-0.053	0.009	0.291	0.035
W15	Muslim	0.084	-0.053	-0.086	-0.156	0.009
W16	Odingo	0.084	-0.053	-0.187	-0.232	-0.141
W17	Ayeye	0.017	-0.053	-0.149	-0.279	-0.149

Trace elements in soil (s) and stream sediment (ss)

ELEMENTS	Cu	Pb	As	Cd	Ba	Zn
S_1	0.8	7.2	0.2	3.1	-1.6	2.8
S_2	-1.1	2.1	-0.4	0.7	-2.9	0.5
S_3	-2.3	0.9	-0.1	0.7	-3.4	0.4
S_4	-1.8	1.2	-0.4	0.7	-3.5	0.4
S_5	-0.3	3.2	-0.1	1.4	-2.9	2.6
S_6	-0.6	1.9	-0.4	2.8	-2.8	2.6
S_7	-1.0	2.3	0.2	0.3	0.3	1.1
S_8	0.2	2.8	0.4	2.9	2.9	4.2
S_9	-1.9	1.5	-0.4	0.7	0.7	1.7
SS10	-0.7	2.1	-0.4	0.7	-3.3	0.9
SS11	0	2.1	-0.4	0.7	-1.8	2.2
SS12	0.1	2.4	-0.4	0.7	-3.2	1.0
SS13	0.7	2.6	-0.4	0.7	-3.1	1.1

Table 6. Factor matrix for water, soil and stream sediments.

Trace elements in water

	Factor 1	Factor 2	Communalities
As	0.839	0.109	0.715
Cd	0.679	0.575	0.791
Cu	-0.403	0.766	0.749
Pb	-0.555	0.312	0.406
Eigenvalues	1.635	1.026	
% of Variance	40.865	25.656	
Cumulative %	40.865	66.521	

Major oxides for soil and stream sediments

	1	2	3
Na_2O	0.810	0.353	-
K_2O	0.860	-	-0.411
Fe_2O_3	0.730	-	0.609
CaO	0.464	0.825	-
MgO	0.854	-0.356	-
Eigen vales	2.872	1.048	0.567
Percentage of variance	57.448	20.964	11.345
Cummulative percentage	57.448	78.412	89.757

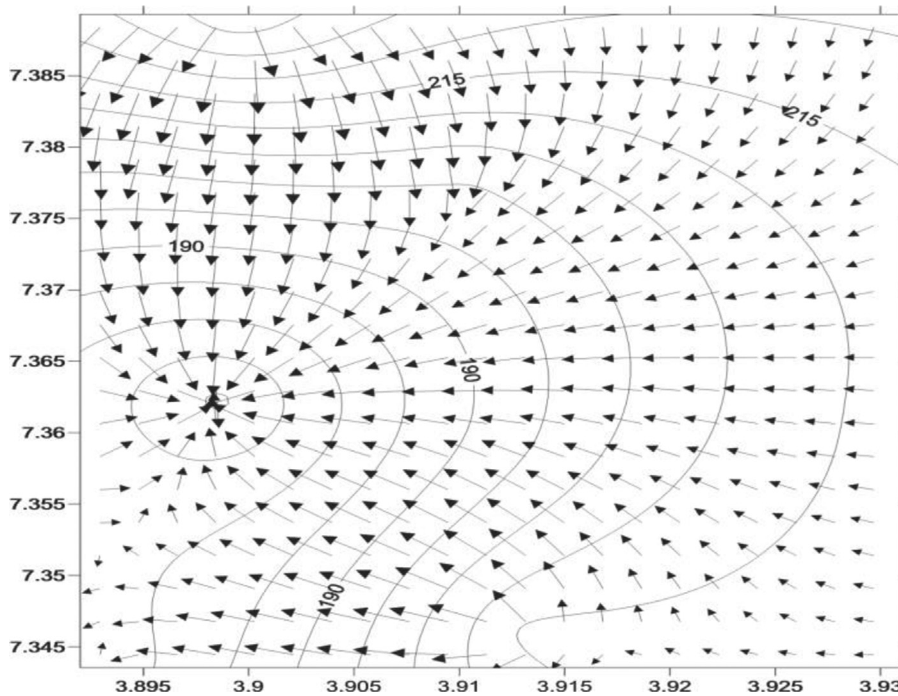

Figure 2. Piezometric map of water in the study area.

4.2.1. Correlation coefficient for water, soil and stream sediment of the study area

The correlation matrix in water showed very strong and positive correlation in the following Zn – Cd; Pb – Fe; Ca - As; K - As; Mg - As; with 'r' values of 0.983; 0.900; 0.797; 0.683 and 0.761 respectively indicating that the elements were governed by the same geochemical factors and are from the same source. While Mg–Ca ('r' = 0.607) though indicates same geochemical environment are essential elements necessary for growth of both plant and animal in the study area (Table 4). High and positive correlation was observed in the major oxides of soil and stream sediment between K_2O– Na_2O; MgO–K_2O; MgO–Fe_2O_3 with 'r' values 0.623, 0.786, 0.628 respectively while trace metals for soil and stream sediment showed that Pb–Cu, Ba–Cu, Cd–Pb, As–Zn, Cd–Zn, Ba–Cd with 'r' values 0.643, 0.604, 0.645, 0.707, 0.724, 0.559 are all influenced from the same anthropogenic source in the study area.

This anthropogenic influence are dominantly through indiscriminate dumping of refuse; lack of drainage that causes effluent water run-offs; sewage run-offs; indiscriminate washing of chemicals used for various things in the water channels.

4.2.2. Geo-accumulation index for water, soil and stream sediment of the study area

The I_{geo} is less than zero across all the trace elements. This indicates that the water samples are practically uncontaminated with any of the trace metals (Table 5).

4.2.3. Factor analysis for water, soil and stream sediment of the study area

For the analyzed water samples, Factor 1 has an eigenvalues of 1.65 summing up to 40.85% of the variance. There exists a high loading value for As and Cd, while Cu and Pb has negative loading values indicating that they are from different source (anthropogenic). For the factor 2, the Eigenvalues is 1.026 summing up to 25.66% of variance, there exist a high loading value for Cu, a moderate loading value for As and Cd, and a low loading value for Pb indicating that these are also from different sources. The results aligned with the correlation matrix (Table 4) which suggests that elements are from the same anthropogenic geochemical zone (Table 6). Results of soil and stream sediment revealed the same source for major oxides in Factor 1, while factor 2, showed that MgO alone comes from another source that is not too pronounced; Factor 3, revealed that K_20 and Fe_2O_3 are almost from different sources.

Table 7. Risk index (K_o) for trace elements in soil (s) and stream sediment (ss).

ELEMENTS	Cu	Pb	As	Cd	Ba	Zn
S_1	2.8	186.6	1.7	13	0.5	10.1
S_2	0.7	6.3	1.1	2.5	0.2	2.2
S_3	0.3	2.9	1.4	2.5	0.1	2.0
S_4	0.4	3.3	1.1	2.5	0.1	2.0
S_5	1.1	13.6	1.4	4.0	0.2	9.3
S_6	0.9	6.0	1.1	10.3	0.2	9.3
S_7	0.7	7.2	1.7	3.3	0.3	3.2
S_8	1.7	10.2	1.9	1.1	0.3	27.7
S_9	0.4	4.2	1.1	2.5	0.1	5.0
SS10	0.9	6.2	1.1	2.5	0.2	2.7
SS11	1.5	6.6	1.1	2.5	0.4	6.7
SS12	1.5	7.9	1.1	2.5	0.2	2.9
SS13	2.4	9.1	1.1	2.5	0.2	3.2

Result observed in Factor 1, correlates with the correlation matrix.

4.2.4. Hydro-geologic interpretation

The piezometric map (Figure 2) indicates direction of water flow. Direction of water flow is to the southwest of the map. The flow point also depicts the area where there is the highest concentration of the heavy metals that may have been released from the influx of organic matter, since the water is flowing from a high point to a lower point.

5. Soil and stream sediments

5.1. Major oxides

Concentrations for soil and sediments revealed ranges of oxides as follows: Fe_2O_3 from 3.30 - 7.15% with mean of 5.23 in the sediment; 2.17–6.06% with mean of 4.04 in the soil; CaO from 0.74-0.99% with mean of 0.84 in the sediment; 0.31–2.97% with mean of 1.48 in the soil; MgO from 0.22-0.98% with mean of 0.41 in the sediment; 0.08–0.48% with mean of 0.27 in the soil; Na_2O from 0.01-0.02% with mean of 0.02 in the sediment; 0.01–0.07% with mean of 0.03 in the soil; K_2O from 0.17-0.36% with mean of 0.22 in the sediment; 0.10–0.41% with mean of 0.22 in the soil. Dominance of Fe_2O_3 in the sediments when juxtaposed to soil confirmed the effect of poor sanitary and waste/sewage disposal facilities in the study where their stream channel is used mainly as waste disposal tank. Dominance of other oxides (CaO, MgO, Na_2O, K_2O) were found in all the areas this showed the oxides had been majorly contributed from the weathering of aluminosilicates. Evidence of Ferromagnesian and aplite rich minerals from weathering of rocks on the soil revealed the impact of each oxide on the environment. A significant correlation also confirmed the above outcome (Table 4).

Factor analysis described other factors that could affect the media apart from metal contamination (Tijani, 2000). Factor 1; consists of all major oxides which revealed that they are those controlling the chemical character of the soil and stream sediments, and they account for 57% of the total variance of the variables with Eigen value of 2.8; furthermore the relatively high positive correlation is a reflection of the influence of community on the soil and stream sediment chemistry which affirms the indiscriminate dumping of industrial and market sewage waste in the soils and sediments of the study area. Factor 2; consists of all the oxides except Fe_2O_3, K_2O and it suggests a natural environment for the oxides, but it still showed the influence of CaO on the chemistry. Factor 3; affirms the same controlling environment for the oxides with the exception of CaO and Fe_2O_3. Therefore, the chemical character observed is mostly the major oxides analyzed but it is dominated by CaO and Fe_2O_3 (Table 6).

5.2. Trace elements

Mean concentrations showed an increasing order of Zn > Pb > Cu > As > Cd. Concentration of trace metal is much higher in soil than stream sediments, which indicates migration from stream sediments into the soil samples. Highest concentrations were found in Elere River (LC13), Eyin Grammar (LC1) and Surulere (LC5) due to sewage sludge, steel and iron works and refuse incineration activities observed. When compared with crustal average concentration of the metals were observed to be higher than the recommended average with the exception of Ba. Since the study was conducted in an over-crowded area the impact of human activities is mainly predominant (Table 3).

A strong and positive correlation was observed Cu–Pb (0.643), Cu–Ba (0.604), As–Zn (0.707), Cd–As (0.612), Zn–Cd (0.724); effect of human activity such as sewage sludge, steel and iron works and refuse incineration, effluent run-offs were revealed from the outcome which indicates all the elements to be of the same source due to the strong and positive correlation it showed (Table 4).

The outcome obtained was found similar to the work done by Wei et al. (2019), Abou El-Anwar (2019) and Tijani et al. (2004).

5.3. Index of geo-accumulation

Geo-accumulation classification index ($I_{geo)}$ (Hakanson, 1980) for soil and stream sediment revealed all metals to be practically uncontaminated with the exception of Zn, Cd and Pb in soil with values 2.8; 3.1 and 7.2 respectively, which is between moderately contaminated to highly to very highly contaminated. Possible sources are from leaded gasoline and tire wears, automobile emissions, batteries and municipal waste effluents/sewage sludge of which are human activities found in the study area.

Therefore, the order of degree of anthropogenic factor contamination or enrichment in both soil and stream sediments is Pb > Zn > Cd > Cu > As > Ba (Table 5).

5.4. Risk index

Risk index in soil and sediments showed Zn (6.7 for stream sediment and 27.7 for soil), Cd (2.5 for stream sediment and 13 for soil) and Pb (9.1 for stream sediment and 186.6 for soil) to be between dangerous to extremely dangerous (Table 7).

5.5. Pollution prevention and environmental sustainability

Pollution forestalling is a key issue to environmental sustainability. To forestall the continual pollution of metals in groundwater and soils of the study area the following must be done: a drastic measure must be taken to evacuate the dump site around it; another way is to close the groundwater around the dump site and dig another well at a safe area; plants that are good in adsorbing and absorbing metals must be cultivated on the affected soils; a cultural change, that encourages more anticipation and internalizing of real environmental costs by those who may generate pollution must be instilled on the people in the environment; since it is everyone's responsibility is to utilize his/her knowledge to take actions that are protective of human health and the environment; finally a comprehensive pollution prevention program should arranged thus forestalling further pollution of these metals.

6. Conclusion

In conclusion, heavy metal results in ground water revealed that all of the metals are found within the permissible limits with the exception of TDS this is attributed to weathering, and wastes disposed at the dump site found in the study area; high K found within the study area becomes a health issue if taken by people with health high risk while Cd, Zn and Pb was observed to be above the standard in the soil and stream sediment. Organization of enlightenment program on the impact of polluted metals on the environment in form of seminars should be put in place for the people leaving in the area; remediation of stream sediment and soils of the area must also be effected, to prevent depletion by these metals and also giving the environment a future hope, thus sustaining the environment and public health of the study area.

Declarations

Author contribution statement

LANIYAN, T. A: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

MORAKINYO, O. M: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data will be made available on request.

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The authors declare no conflict of interest.

Additional information

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